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HIGH OUTPUT CIRCULATORY FAILURE AS A DISTINCT SYNDROME*

Some patients with a diagnosis of congestive heart failure have a basal cardiac output well above the normal range. It is understandable that a weakened heart might achieve a normal output in the presence of stimuli not found in the normal person, but it is not reasonable to suppose that cardiac weakness as such could lead to an increase in basal cardiac output. Therefore, in patients who have the so-called high output type of circulatory failure, a source of cardiac stimulation not present in normal persons must be postulated. A consideration of the causes of high output failure and of the characteristic features of the syndrome reveals that the resistance to outflow of blood from the systemic arterial tree is reduced. This could be the change which elicits the increase in cardiac output.[1, 2]

Differentiation of True Congestive Heart Failure and High Output Circulatory Failure

The similarities between true congestive failure and high output failure are related to the fact that retention of NaCl and water occurs in both. The rise in extracellular fluid volume which is a direct consequence of the positive salt balance leads to edema, accumulation of fluid in body cavities, increased blood volume, increased venous pressure, cardiac dilatation, pulmonary engorgement and dyspnea.

There are two principal differences between the two syndromes: First, the total peripheral resistance is below normal in most or all cases of high output failure, while typically it is elevated in true congestive failure. Second, cardiac output, by definition, is increased in the former while it is normal or decreased in the latter. Corollaries to the increased cardiac output in high output failure are the shortened circulation time and decreased arteriovenous oxygen difference; these are increased in true congestive failure. Further evidences of cardiac stimulation which may be seen in high output failure are the increased amplitude of waves in the ballistocardiogram, elevated heart rate and widening of the pulse pressure. Both the lowered peripheral resistance and increased stroke volume contribute to the latter change. The increase in pulse pressure in high output failure usually is achieved through a decrease in diastolic pressure as well as through an increase in systolic pressure, so that the mean arterial pressure may not be significantly altered. The peripheral resistance (calculated from the relationship $R = \frac{P}{F}$, where R is resistance, P is mean arterial pressure and F is flow) is decreased, since flow is increased and mean pressure is not correspondingly increased.

Since the heart in high output failure may be responding as a normal heart would be expected to respond under identical circumstances, there is no evidence of cardiac weakness. It is possible that weakness could develop eventually, as it does in hypertension. If, as seems reasonable, the heart is not weak it is particularly inappropriate to call this syndrome high output heart failure. High output circulatory failure is less objectionable, but "low peripheral resistance syndrome" would be a more accurate and descriptive designation. The rather noncommittal name "chronic congestive circulatory failure" could include both true congestive heart failure and high output circulatory failure.

Mechanisms of Salt and Water Retention

In patients with true congestive heart failure,[3, 4, 5] the following characteristic changes in renal function occur: 1) When cardiac output is significantly decreased, renal blood flow shows a still greater per cent reduction. 2) Glomerular filtration rate is decreased to a lesser degree than the decrease in renal blood flow. 3) The ability of the kidney to excrete sodium is decreased markedly. 4) The processes concerned with reabsorption of sodium by the tubule are not impaired and actually may be more effective. The latter change is attributable to the action of aldosterone, which is produced in increased amounts.[6, 7, 8] Since the load of sodium filtered is decreased and reabsorptive activity of the tu-

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bules is maintained or increased, the amount of sodium excreted is decreased. 5) The ability of the kidney to excrete water is not seriously impaired. The retention of water appears to be secondary to salt retention, and only enough is retained to maintain isotonicity of body fluids.

In high output circulatory failure, the retention of NaCl and water may be attributed, at least in part, to a decrease in renal blood flow and glomerular filtration rate related to a disproportionate decrease in the extrarenal fraction of the total peripheral resistance. It is reasonable to postulate such a change in the ratio of renal to extrarenal resistance, since normally the tonus of arterioles in the kidney is low as compared with arteriolar tonus in the extrarenal parts of the systemic circuit. Therefore, in the presence of a general systemic vasodilator influence the resistance in the kidney can decrease only slightly, while a great decrease can occur in the resistance in the skin, splanchnic viscera and other sites. The renal blood flow is decreased in certain conditions which lead to high output failure, and since the cardiac output is elevated, the ratio of the renal blood flow to the cardiac output is greatly decreased. Whereas the renal flow fraction normally is around 20 to 25 per cent, in some cases with high output failure it is below 5 per cent. It is possible that aldosterone production is increased in this syndrome also, and this would contribute to salt retention just as it does in congestive heart failure.

Thus it appears that retention of NaCl and water may be brought about, either as a consequence of left ventricular weakness with a corresponding tendency of the cardiac output to decrease, or as a consequence of the shunting of blood away from the kidney (or some other organ) in the absence of cardiac weakness.

Mechanisms for the Increase in Cardiac Output

There are several reasons for postulating that the decrease in peripheral resistance in high output failure is the initial change in the cardiovascular system that leads to the other changes characteristic of the syndrome. First, in arteriovenous fistula which leads to high output failure (perhaps in its purest form) the initial hemodynamic alteration obviously is the reduced resistance to outflow of blood from the systemic arterial tree. Second, decreased peripheral resistance occurs in beriberi, severe anemia, hyperthyroidism, Paget's disease, patent ductus arteriosus, hyperthyroidism and certain types of chronic pulmonary disease, all of which may lead to high output failure. Third, the high cardiac output can be explained as a compensatory response to the low peripheral resistance. Fourth, as discussed above, the renal retention of salt and water may be caused by a shunting of blood away from the kidney by a disproportionately large decrease in resistance in the extrarenal portion of the systemic circuit.

An increase in cardiac output is observed following any change which causes a lowering of the peripheral resistance, unless a condition exists at the same time which limits the return of blood to the heart. A number of vasodilator drugs cause an increased cardiac output in subjects in the recumbent or moderate Trendelenburg position. In subjects in the orthostatic position, vasodilator drugs cause a decrease in cardiac output since venous return is not maintained. When a systemic arteriovenous fistula is opened in anesthetized dogs, allowing a flow of 1200 to 1600 ml., the heart rate and cardiac output immediately increase by an amount usually within the range of 50 to 100 per cent of the amount of fistula flow.[9] It is probable that the compensation for the flow across a shunt of moderate size would be virtually 100 per cent in unanesthetized animals or man. An increase in heart rate is an essential part of the immediate compensatory rise in cardiac output. In the long run, a rise in venous pressure and increased stroke volume also may contribute to the elevated output, but initially the right atrial or end-diastolic right ventricular pressure do not rise and even may decrease immediately after opening the shunt. Vasodilator drugs usually cause a fall in right atrial pressure. Thus, the elevated cardiac output in response to low peripheral resistance is caused by cardiac acceleration, probably reflexly induced from a fall in pressure in the sino-aortic zones, early after the decrease in resistance is established; ultimately, however, the response of a heart of normal strength to an elevated venous pressure may become an important basis for the high output. The chronic elevation of the venous pressure is related to the increase in extracellular fluid volume occurring as a result of decreased renal excretion of salt and water.[1] In recent experiments it has been shown that such retention begins immediately after opening a fistula[9] and continues in chronic preparations.[10]

Weiss and Wilkins,[11] in 1937, noted similarities between the effects of systemic arteriovenous fistula and chronic thiamine deficiency, and they observed that circulatory changes produced by large doses of thiamine in patients with beriberi heart disease are similar in important respects to those associated with closure of an arteriovenous fistula. The pattern of cardiovascular changes in beriberi heart disease is the typical high output failure syndrome.[12, 13] To accept vasodilatation as the primary defect in the circulatory system in beriberi would be to accept the similarities between AV fistula and beriberi heart disease as fundamental. Renal function has been studied in only a few cases with beriberi, and in these renal blood flow and glomerular filtration rate were below normal despite a high cardiac output. It is possible, of course, that in the cases with more severe and prolonged thiamine deficiency a cardiac weakness factor also appears.

Davies and Kilpatrick[14] found renal blood flow and glomerular filtration rate reduced in patients with high output failure due to chronic cor pulmonale. The average for 10 patients was about one half the average for normal individuals. If the

THE ANNUAL MEETING
and
30th Annual Scientific Sessions
of the
AMERICAN HEART ASSOCIATION
October 25 through October 29, 1957

Headquarters: **Hotel Sherman**
Chicago, Illinois

ALL MEETINGS WILL BE HELD AT THE HOTEL SHERMAN

FRIDAY, OCTOBER 25 — Advance Registration

MEETING SCHEDULE

FRIDAY, OCTOBER 25 all day — Special Scientific Session for Physicians in General Medicine
8:00 P.M. — Special Session—
Instrumental Diagnostic Methods in Cardiology

SATURDAY, OCTOBER 26 — 30th Annual Scientific Sessions
Program of Council on Community Service and Education
through — Program of the Council on Rheumatic Fever and Congenital Heart Disease
MONDAY, OCTOBER 28 — Program of the Staff Conference of Heart Associations

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MONDAY, OCTOBER 28 — A. H. A. Assembly Panel Meetings

TUESDAY, OCTOBER 29 A.M. — Annual Meeting of the A. H. A. Assembly—
elections—panel reports
P.M. — Luncheon and Business Meeting—Staff Conference

SOCIAL FUNCTIONS

FRIDAY, OCTOBER 25 — Staff Conference Dinner

SATURDAY, OCTOBER 26 — Council on Rheumatic Fever and Congenital Heart Disease—Luncheon

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SUNDAY, OCTOBER 27 — Community Service and Education—Luncheon
A. H. A. Annual Dinner Dance—presentation of Gold Heart awards

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MONDAY, OCTOBER 28 — A. H. A. Assembly Luncheon

AMERICAN HEART ASSOCIATION **ADVANCE REGISTRATION**

Name ..... (Please Print) (Last Name) (First Name)

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City ..... Zone..... State.....

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Room with Double Bed for 2 Persons				$10.45 $14.95	$11.45 $15.45	$11.95 $15.95	$12.95 $16.45	$13.45 $16.95	$13.95 $17.45	$14.45 $17.95
Twin bedded rooms				$13.45	$13.95	$14.45	$14.95 $16.95	$15.45 $17.45	$15.95 $17.95	$16.45 $18.95
Alcoves (Sitting Room-Bedroom Combination)								$22.95	$23.95	$24.95
Parlor and One Twin Bedroom							$23.95	$29.95	$36.95	$38.95
Parlor and Two Twin Bedrooms									$54.90	$65.00
Two Rooms with Connecting Bath (Not available with Twin Beds)							For Two Persons Three Persons Four Persons		$13.90 $17.90 $21.90	$15.90 $19.90 $23.90

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_____Parlor, one double room with bath.....Rate $_____ to $_____ per room
_____Parlor, two double rooms with bath.....Rate $_____ to $_____ per room

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NOTICE

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FOR THE LADIES

The Chicago Heart Association will be your host during the American Heart Association Annual Meetings. For your convenience they are providing a Hospitality Lounge which will be open Friday, October 26 through Monday, October 28.

Hostesses will be there to greet you and to take care of your registration. The lounge will provide an ideal spot to meet your friends. Playing cards and magazines will be available as well as a list of places of interest, television shows, etc.

SPECIAL EVENTS

Saturday, October 26

Art Institute
2:00 P.M. to 4:00 P.M. — Interesting and informative visit to Chicago Art Institute

Sunday, October 27

Sightseeing
1:30 P.M. to 4:00 P.M. — Bus tour of Chicago, including the Chrysanthemum Show at Garfield Park and the Giant Heart exhibit in the Museum of Science and Industry

Monday, October 28

Fashion Show and Tea
3:00 P.M. to 4:30 P.M. — Wedgewood Room, Marshall Field and Company

NOTICE

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HAWAII in 1958???

POST CONVENTION TRIP FROM SAN FRANCISCO FOR SCIENTIFIC MEETING IN HAWAII

PLAN 1

Round trip by Steamer	$260 and $277.50 per person and up

PLAN 2

Round trip by Plane	$320 per person—first class $250 per person—tourist

PLAN 3

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Please indicate your interest below. If enough interest is shown we will proceed with arrangements. Details would then be available at our October meeting in Chicago.

All above prices are approximate

I am tentatively planning to take the trip to Hawaii in 1958

self ( ) wife ( ) others ( ) indicate number

Plan 1 ( ) Plan 2 ( ) Plan 3 ( )

SITES OF FUTURE SCIENTIFIC SESSIONS & ANNUAL MEETINGS

1958 — October 24-28	San Francisco, California
1959 — October 23-27	Philadelphia, Pennsylvania
1960 — October 21-25	St. Louis, Missouri

TENTATIVE

1961 — October 27-31	Miami Beach, Florida
1962 — October 26-30	Chicago, Illinois

renal blood flow in these patients is expressed as the per cent of the cardiac output, the range is 2.0 to 15 per cent with an average of 7 per cent as compared with an average of around 22 per cent in normal subjects. It is evident that the kidneys do not share in the increased circulation in high output failure associated with beriberi or cor pulmonale. This demonstrates that the extrarenal fraction of the peripheral resistance is disproportionately lowered in these diseases, just as it is in systemic arteriovenous fistula.

Consequences of Hypervolemia

It is visualized that hypervolemia develops as a compensatory device in the high output failure syndrome; however, it appears that the increase in blood volume may be great enough to lead to difficulties. The principal dangers in hypervolemia are first, the possibility that the ventricles may become dilated to the extent that the dilatation per se contributes to an acute decrease in cardiac output, and second, that the pressure in the pulmonary capillary bed may become increased to the point of producing transudation into the alveoli. The dangers of fluid administration to patients with hypervolemia are obvious, but the consequences of administration of vasoconstrictor drugs are not quite as apparent. The ill effects of such drugs in hypervolemia are related to the fact that they promote a shift of blood from the systemic circuit into the already engorged pulmonary circuit, and this may cause a rise in pulmonary capillary pressure sufficient to produce pulmonary edema. In dogs, doses of vasoconstrictor drugs which do not produce pulmonary edema in the presence of a normal blood volume will have this effect if the blood volume is moderately increased before the drug is injected.

The low peripheral resistance hypothesis also explains readily the fact that further cardiac dilatation may occur in a patient with beriberi heart disease who is treated too vigorously with thiamine. As arteriolar tonus is regained in the presence of hypervolemia, venous pressure shows a further rise. The same type of effect on the heart is seen sometimes when a large chronic arteriovenous fistula is closed. Withdrawal of blood may be beneficial in such cases.

The degree of pulmonary congestion in a patient with chronic hypervolemia is least in the orthostatic position, but is increased when the patient lies down. Immediate transfer of blood from the systemic to the pulmonary circuit occurs as a result of the effects of gravity when the recumbent position is assumed. However, there is also a gradual increase in blood volume while the patient remains recumbent, as edema fluid moves from the interstitial space through the capillary walls; thus the blood volume shows nocturnal increases in patients with chronic hypervolemia and edema. The rise which occurs during the night, and the consequent increase in pulmonary engorgement, perhaps may explain the development of acute dyspnea.

The most practical indices of the severity of the increase in volume of blood in the pulmonary circuit and cardiac chambers probably are: (1) the amount of pulmonary engorgement as indicated by dyspnea, (2) evidences of transudation of fluid into the alveoli, (3) the degree of cardiac dilatation, and (4) the level of pressure in the great veins and right atrium.

It appears that vasoconstrictor influences may build up in some patients with chronic circulatory failure during the day while they are up and about. Possibly renal ischemia and the angiotonin mechanism are involved in this reaction.[15] Furthermore, the patient's ability to excrete salt is considerably less during the up-and-about period than during recumbency.[16] The reduced salt excretion during the day in patients with congestive heart failure no doubt is related to a further decrease in glomerular filtration rate produced by the orthostatic position, and possibly to a further increase in the production of aldosterone.

Summary

In most or all of the conditions leading to high output circulatory failure there is reduced resistance to run-off of blood from the systemic arterial tree. A chronically low peripheral resistance appears to be sufficient to cause development of the full-blown high output failure syndrome. Cardiac weakness and failure may or may not develop in the course of the disease. When cardiac failure occurs, this would be expected to contribute to a further rise in extracellular fluid volume and a reduction in cardiac output from the high level seen before failure. The problem of transfer of blood from the systemic circuit to the pulmonary circuit as a result of recumbency and of vasoconstrictor influences is discussed.

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The opinions and conclusions expressed herein are those of the author and do not necessarily represent the official views of the Scientific Council of the American Heart Association.

THE AMERICAN HEART ASSOCIATION

Invites You to Attend

THE ANNUAL MEETING

October 25 Through 29, 1957

and

THE 30TH SCIENTIFIC SESSIONS

COMMEMORATING

THE TERCENTENARY OF WILLIAM HARVEY

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Important Deadline . . .

ABSTRACTS OF PAPERS FOR THE 30TH SCIENTIFIC SESSIONS AMERICAN HEART ASSOCIATION

The 30th Scientific Sessions of the American Heart Association will be held in Chicago, Illinois, on October 25 through 28, 1957, as part of the Association's Annual Meeting. Early submission of abstracts is advised; *the deadline is June 15, 1957.* Abstracts will be accepted only on forms which can be obtained from the Medical Director, American Heart Association, Inc., 44 East 23rd Street, New York 10, New York.

Papers intended for presentation should be based on original investigations in, or related to the cardiovascular field. Abstracts must be submitted in triplicate, in a form suitable for publication in the Proceedings.

The Scientific Sessions again will feature a section for Scientific Exhibits. Requests for space and application forms also may be obtained from the Association's Medical Director. *The deadline for these applications is June 15, 1957.* All exhibit applications will be submitted for decision to the Program Committee of the Scientific Council.

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